South Asia Conference on Technologies for Poverty Reduction, New Delhi, 10 – 11 October, 2003

ROLE OF MODERN SCIENCE AND TECHNOLOGIES IN AGRICULTURE FOR POVERTY ALLEVIATION IN SOUTH ASIA[1]

BY

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Introduction

Around 70 percent of poor and food-insecure people reside in rural areas, although poverty and food insecurity appear to be growing in urban areas as urbanization proceeds apace in most of the developing countries. Productivity gains are essential not only for economic growth, but also for maintaining adequate food supplies for the growing world population. Therefore, accelerated public investments are needed to facilitate agricultural and rural growth through: High yielding varieties resistant to biotic and abiotic stress factors, Environment friendly production technology, Availability of reasonably priced inputs in time, Strong extension services, Dissemination of information, Improved infrastructure and markets, and Primary education, health care, and adequate nutrition.

Need for Application of New Technologies

According to United Nations projections, world population is expected to exceed 8.0 billion by 2025. On an average, 73 million people will be added annually, and 97% of the projected growth will take place in the developing countries. Nearly 1.2 billion people live in a state of absolute poverty (FAO 1996). About 800 million people are food insecure, and 160 million pre-school children suffer from malnutrition. A large number of people also suffer from deficiencies of micronutrients such as iron and vitamin A (Pinstrup-Anderson and Cohen 2000). Food insecurity and malnutrition result in serious public health problems and a lost human potential in developing countries. The major problems faced by the rural poor include: Low productivity, Food insecurity, and Poor nutrition.

The availability of land is decreasing over time, and such a decrease is expected to be much greater in the developing countries than in developed countries especially in Asia. Grain production has shown a remarkable increase between 1950 and 1980, while a marginal increase was recorded between 1980 and 1990. There is a need to increase the production of pulses, milk and animal foods from to meet demands of increasing population.

The South Asian region is home to the largest number of poor people in the world. Nearly one-third of all malnourished people in the world live in this region and they need access to affordable and nutritious food (Table 1). Food security is a critical concern in South Asia, against the current background of rapid population growth. The resource poor small-scale farmers, who contribute substantially to food production in this region, need to be empowered with such appropriate technologies to enhance sustainable agricultural productivity and production.

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[1] Paper presented at the Conference on 'Technology for Poverty Reduction: Working towards a South Asia strategy' organized by Intermediate Technology Development Group-South Asia (ITDG-South Asia), at the British Council, New Delhi, 10-11 October, 2003.

Table 1. Estimates and projections of the incidence of chronic under-nutrition in developing countries.

Region	Year	Total population (millions)	Undernourished	
			% of total population	Millions
Sub Saharan Africa	1969-71	268	36	103
	1990-92	500	43	215
	2010	874	30	264
Near East / North Africa	1969-71	178	27	48
	1990-92	317	12	37
	2010	513	10	53
East Asia	1969-71	1,147	41	475
	1990-92	1,665	16	268
	2010	2,070	6	123
South Asia	1969-71	711	33	238
	1990-92	1,138	22	255
	2010	1,617	12	200
Latin America	1969-71	279	19	53
	1990-92	443	15	64
	2010	593	7	40
Total	1969-71	2,583	35	917
	1990-92	4,064	21	839
	2010	5668	12	680

Source: FAO. 1996. Food, Agriculture and Food Security: World Food Summit Technical Background Documents, vol. 1, p. 9.

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of south Asia, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the semi-arid tropics. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT's work has a great relevance to the South Asia region, which includes Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. These countries though differ in their size of population, geographical areas, and economy, have marked similarities in their economic, agricultural, as well as in their approach to education, health services and welfare activities. The incidence of poverty is more in rural areas, e.g. in Nepal and Bangladesh, rural poverty is more than double of the urban poverty. The estimates of FAO indicate that by 2010, Asia will account for one half of the world's malnourished population, of which two-thirds will be from South Asia.

Regional Approach to Priority Setting in South Asia

ICRISAT works with other international agricultural research centers (IARC) in the region for harnessing synergies and reduce duplication of efforts. The joint meeting of IARCs and Asia-Pacific Association of Agricultural Research Institutions (APAARI) held in July 2001 identified the following research priorities for this region.

- Irrigated systems: Water and soil resources, systems diversification, pest and weed management, and market and post harvest issues.
- Indo-Gangetic plains and coastal areas: Low productivity, water and soil issues, biotic and abiotic stresses, undeveloped markets, and post-harvest issues.
- Semi-arid/arid regions: Water and soil issues, low productivity, diversification and income generating opportunities, and post-harvest management.
- Hills and mountain ecosystems: Water and soil issues, deforestation, loss of biodiversity, poor access to markets, and post-harvest issues.

Modern science offers tremendous opportunities for improving the livelihood of poor farmers as well as protecting the environment. There are skeptics who may question the benefits of modern science, and even blame science for many of our current problems. Some are opposed to poor farmers using purchased inputs such as improved seeds, fertilizers and chemical pesticides since it makes them dependent on markets and private suppliers, and less self-reliant. We must remember, however, that modern science can serve poor farmers only if scientists focus on the interests of the underprivileged and smallholder farmers. We call this 'Science with a Human Face', and it is the guiding mantra of ICRISAT. Our work has to be designed to solve poor people's food and nutrition problems through good science in tandem with appropriate policies and institutions. Technology development must be demand driven i.e., it is based on the socio-economic and environmental needs and circumstances of resource-poor farmers. In many cases, existing institutions and policies are biased against the poor – the technologies may be too costly, and other enabling factors like information and communication technologies (ICT), farm credits and inputs may not be available to the poor at the coat they can afford.

Conventional Technologies for Sustaining Food production

Farmer-innovated agro-technologies

Farmers have long practiced sustainable crop production by managing:

- Soil fertility management by recycling organic waste

- Green manuring
- Crop rotations
- Watershed management
- Pest control

Farmers are benefiting substantially from their own innovations – for example (Pretty and Hine, 2000).

- Home gardening with vegetables and fruit trees
- Adding new productive elements into agriculture such as fish in rice paddies
- Better use of water
- Improvement in yield through integrated pest management

Studies also found that farmers require more information on relationships between pests and predators, plant growth and soil moisture, and crop and livestock. Social learning contributes significantly to sustainable agriculture as well as to innovation and adoption of new ideas.

The world is more food secure today largely as a result of development and deployment of high yielding varieties, fertilizers use, and irrigation. A significant achievement of the Green Revolution was the stabilization of production and prices of food grains. Fluctuations in the food grains production have declined significantly in both irrigated and rainfed regions since 1980s (Pal et al. 1993; Pandey et al. 2000). The basic concepts of science, which made the Green Revolution a reality is still relevant today (Huang et al. 2002; Evans 2001).

Green revolution catalyzed by CIMMYT and IRRI resulted in >70% of the world's rice and wheat being planted to improved high yielding cultivars developed from breeding material supplied by IRRI and CIMMYT. Similarly the national programs globally have released around 500 cultivars (both varieties and hybrids) of sorghum, pearl millet, chickpea, pigeonpea and groundnut based on the germplasm and breeding material provided by ICRISAT.

Grey to Green Revolution: Research for Impact at ICRISAT

The researchers are now trying to make the Green Revolution more sustainable by introducing resource conservation technologies and greater diversification of farming systems. ICRISAT is working with partners to diversify cereal-based systems in South Asia with chickpea, pigeonpea, mungbean, lentil, and other legumes. Integration of legumes in rice-wheat system will also add "natural" fertilizer in the form of nitrogen-fixation. The introduction of short-duration pigeonpea developed at ICRISAT has helped to integrate legumes in crop rotations in Central India (Bantilan and Parthasarathy 1999). During the 'Green revolution', the environment was adapted/modified to skip the varieties by providing fertilizer and irrigation. However, if the rainfed areas have to benefit from R&D, adapting the crops to the environment will allow farmers to get more out of their natural resources, and manage these resources more efficiently, turn adversity into opportunity, and change the marginal grey areas to green. This 'Grey-to-Green Revolution' must aim at achieving maximum returns form marginal soils under rainfed conditions.

Improved varieties with high yield and resistance to insect pests, diseases, and drought

Sorghum

- Nearly half of India's 10 million hectares of sorghum is planted with hybrids. More than 70% of the sorghum hybrids are from the private sector, and 75% of these private sector hybrids have been developed from ICRISAT-bred parental hybrid lines, or on the proprietary parental lines developed from ICRISAT-bred improved germplasm.
- Midge-resistant varieties such as ICSV 197, ICSV 745, ICSV 735, and ICSV 804, which have been released in India and Myanmar, and used in breeding programs extensively in Asia, Africa, Australia, and USA.
- Diverse male-sterile and restorer lines with resistance to insect pests and diseases, that have been used extensively by the private seed sector.

Pearl millet

- The greatest impacts have occurred in India where six million hectares (more than 60% of the total pearl millet area) in India is planted with more than 70 hybrids, of which at least, 80% hybrids are from the private sector. More than 60 of these hybrids are based on ICRISAT-bred hybrid parents (mostly seed parents), or on the proprietary hybrid parents developed from ICRISAT-bred improved germplasm.
- The hybrid technology has also contributed to employment generation and enhanced income to farmers at the seed production stage.
- Pearl millet hybrid seed production in India, most of it done during the summer season in one district of Andhra Pradesh, generates an additional income of US$1 million a year to the seed producing farmers' community in this district.

Chickpea

- Several chickpea varieties derived from material supplied from ICRISAT (particularly ICCV 2, KAK 2, ICCV 10, and ICCC 37) occupy 25% of chickpea area in India. The most significant development had been the development of early maturing disease-resistant Kabuli varieties that can be cultivated in Southern and Central India.
- Chickpea area in the Barind tract of Bangladesh increased from a negligible 200 hectares in 1984 to 14,000 hectares in 2000.
- ICRISAT-derived chickpea varieties, or varieties developed from ICRISAT-bred materials, have been released and adopted by farmers on more than 20,000 hectares in Myanmar and more than 30,000 hectares in Ethiopia.
- ICRISAT-derived varieties have also been adopted in non-traditional environments in Australia and Canada (spill-over benefits).

Pigeonpea

- More than 800,000 hectares in three states of India (Andhra Pradesh, Maharashtra and Karnataka) are cultivated with two ICRISAT-derived varieties [ICP 8863 (Maruti) and ICPL 87119 (Asha)].
- Pigeonpea is also emerging as an important crop for fodder, fuel and soil conservation in Southern China, where it has rapidly increased from almost zero cultivation in 1998 to about 3,000 hectares in 2001.
- Creation of the world's first food legume hybrid to go into commercial production, demonstrating a 25% grain yield increase.

- Eco-friendly approaches for the management of the pod borer *Helicoverpa armigera* including the development of Pod borer tolerant varieties ICPL 88039 and ICPL 332.

Groundnut

- Several ICRISAT-derived varieties of groundnut have been adopted in seed-village programs in India. Varieties with resistance to leaf diseases and Aflatoxins have been developed. (Upadhayaya et al. 2002), but the extent of their spread is yet to be assessed.
- Based on an integrated disease management program adopted by farmers' groups with respect to four varieties in the Deccan plateau, it is estimated that these varieties will be grown on about 500,000 hectares in 2003.
- Aflatoxin contamination of groundnut is a serious health hazard for humans and livestock. ICRISAT has developed a simple, robust, and cost-effective tool using Enzyme-Linked Immuno Sorbant Assay (ELISA) that costs US$3 per sample against US$18 per sample using other methods.

Raising soil fertility and developing community-scale watersheds

- Crop diversification has proved to be an attractive option for restoring soil fertility, increasing farm income, as well as improving the nutrition of farm families in watersheds of India, Vietnam and Malawi.
- ICRISAT's expertise in participatory watershed management received recognition with private (TATA Foundation) and bilateral (DFID, APRLP) sector funds becoming available to the Asia Project, and additional EU funds made available to support SWMnet in East Africa.
- ICRISAT's focus on micro-dosing to overcome soil fertility constraints in West Africa received recognition.
- ICRISAT's pioneering work in the desert margins of sub-Saharan Africa received recognition with funds from the Global Environmental Facility becoming available for a nine country initiative.

Integrated pest management

- A participatory strategy of combining a range of high-yielding varieties that are tolerant or moderately resistant to insect pests and disease with improved agronomy, chemical spray protection and botanicals and biological control agents where possible, has been followed in this project to achieve profitable returns.
- Several insect resistant varieties have been developed and released for cultivation by the farmers (sorghum midge - ICSV 197 and ICSV 745 in India, and ICSV 735, ICSV 758, and ICSV 804 in Myanmar; pigeonpea pod borer - ICPL 88039, and ICSL 332 in India; and chickpea pod borer ICCV 7 and ICCV 10 in India). Several pearl millet varieties and hybrids based on materials developed at ICRISAT are resistant to downy mildew.
- Reduction in collar rot, stem rot and bud necrosis in groundnut in India has been achieved by using resistant varieties. Reduction of botrytis gray mold in chickpea in Nepal has been achieved through IPM.
- Sunflower has been identified as an effective trap crop for *Spodoptera*. When used by farmers in India and Vietnam, savings of US$20 per hectare were achieved. Combinations of resistant cultivars, early sowing, timing and numbers of fungicide sprays can substantially reduce yield losses caused by foliar diseases of groundnut.

- A combination of new technologies, such as biological control using a virus and fungi, and traditional techniques, such as manual shaking and taking advantage of birds, are being used to manage pod borer damage in pigeonpea.

Information and communication technology

- A novel method of sharing information, knowledge, and skills with poor, inaccessible communities is being piloted by ICRISAT in collaboration with the Commonwealth of Learning and other national partners. This method combines the potentials of open distance learning (ODL) and information and communication technology (ICT).
- ICRISAT, in partnership with Indian Council of Agricultural Research, New Delhi; M S Swaminathan Research Foundation, Chennai; Indira Gandhi National Open University, New Delhi; B R Ambedkar Open University, Hyderabad; Y C Maharashtra Open University, Nashik; and Common Wealth of Learning, Vancouver, Canada, has launched the Virtual Academy for the Semi-Arid Tropics (VASAT).
- The VASAT module is delivered in distance mode through an ICT-enabled rural community information hub established in villages. The rural community information hub involves a low cost connection to the Internet via satellite, allowing easy access to graphics and audio on the worldwide web.

Harnessing Biotechnology to Enhance Food Security

Conventional approaches to germplasm enhancement and crop breeding have had dramatic impacts on food productivity, particularly in systems with high inputs of fertilizer, water and pesticides. However, these approaches not been able to fully control pests, diseases and weeds, which according to two surveys done in 1967 and 1994 accounted for 40% worldwide losses in crop yields (Cramer 1967, Oerke et al. 1994). New biotechnology methods will prove more effective and provide high levels of resistance to these and other stresses. Biotechnologies that are focused on smallholders problems, undertaken in an integrated manner and along with traditional research aimed at improving agronomic practices can help poor farmers increase productivity (Pinstrup-Andersen et al. 1999). Thus, while only part of a total solution that involves better markets, policies, and access to production resources, biotechnology can contribute to addressing poverty issues in developing countries. Modern tools of biotechnology will provide some of the impetus needed to achieve major breakthroughs in agriculture in future (Sharma et al. 2001). These advances will come through the use of modern techniques in:

- Wide hybridization to access pest resistance and quality traits from the wild relatives of crops
- Marker assisted selection to accelerate the introgression of desired genes into high yielding locally adapted cultivars
- Introgression of exotic genes from unrelated organisms to increase resistance to pests, drought, quality traits, nitrogen fixation, etc.

At ICRISAT several candidate genes are being evaluated for imparting resistance to the target insects and diseases, improve adaptation to different abiotic stress factors, and nutritional quality of the produce (Table 2). Such an effort will play a major role in minimizing the insect associated losses and increase crop production, and thus improving the quality of life for the rural poor.

Table 2. Traits for biotechnological interventions for crop improvement in ICRISAT mandate crops.

Crops	Areas of improvement
Sorghum	Varietal improvement for yield and quality, and adaptation to drought. Resistance to shoot fly, stem borer, midge, head bugs, and grain molds.
Pearl millet	Varietal improvement for yield and adaptation to drought. Resistance to downy mildew, stem borers, and head miner.
Pigeonpea	Varietal development for adaptation to drought. Resistance to pod borers and Fusarium wilt.
Chickpea	Adaptation to drought and chilling tolerance. Resistance to wilt, Ascochyta blight, and pod borer.
Groundnut	Varietal improvement for yield, oil content, and adaptation to drought. Resistance to foliar disease, aflatoxins, leaf miner, and *Spodoptera.*

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Food Processing and Industrial uses

Other examples of appropriate technology include alternative uses of crops through value addition, novel food products, and industrial uses of crops. Lack of proper processing and preservation technologies forces farmers to sell their produce in raw form. Many farmers cannot store their food grains and are forced to sell them immediately after the harvest when prices are low. A number of options have been developed for product processing that increases both longevity and nutrition, so that the products could be marketed at higher prices as well as consumed at home.

Looking into the Future

The Green Revolution resulted from science-led appropriate technology. It has been extremely successful in well-endowed areas, but needs to be replicated elsewhere. Success stories of this kind should not be a rare event. We should strive to use science to generate such technologies more often and for the benefit of communities that the Green Revolution has bypassed, especially for those living in semi-arid regions to ensure food security and alleviate poverty. Development of appropriate technologies will require continuous investments in research, especially in publicly funded institutions. Unfortunately, budgets for agricultural research are falling, which means we are being forced to scale down research when the need is for more expanded research programs. Luckily, the recently concluded World Summit on Sustainable Development (WSSD) has put agriculture back on the world's development agenda. Many developed countries, which have made generous contributions to research, are willing to increase or maintain funding and in some instances specifically to the CGIAR that has helped many developing countries in Asia achieve food security.

The agriculture sector is caught in a bind with increasing costs of capital and labour relative to output prices. Industrialization draws the younger, better-educated and more productive labour force out of agriculture, while globalization and trade liberalization call for higher efficiencies through the application of modern science and technology in agriculture. Finding the right formula to sustain agricultural growth in a setting of rapid and dynamic change requires vision, forward-looking policy measures and innovative approaches.

This requires the agriculture sector to continually search and adopt more productive and sustainable technologies. Investment in agricultural research to generate a range of adaptable technologies particularly for small farmers is thus a compelling public policy priority, along with the development of supporting institutions. Even so, national and international support to agricultural research and development and to the diffusion of technology has been on a decline. This is a matter of great urgency as the decline comes at a time when the issues to address (e.g. sustainability, improving rainfed agriculture and productivity of small farms) are quite complex and increasingly crucial. Public sector research particularly through International Agricultural Research Centres (IARCs) and National Agricultural Research Systems (NARS) is essential for ensuring that science serves the needs of the poor people.

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